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ELECTROPHORETIC DISPLAY DEVICE
NOK CORP

Inventor(s): ; KAWAI HIDEYUKI

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Abstract: PROBLEM TO BE SOLVED: To provide a device in which no deterioration of a liquid dispersion is caused and which has excellent durability and shows improved picture image contrast and display quality by successively generating a high level driving voltage for a comparatively short time and then a low level driving voltage.

SOLUTION: This device 20 is provided with a liquid dispersion 10 that is prepared by dispersing pigment particles 10b in a colored dispersant 10a and placed in the space to be sealed between a first substrate 22 and a second substrate 24 and a driving voltage generator 32 for applying a driving voltage between a first electrode 26 and a second electrode 28 to subject the pigment particles 10b to electrophoresis. This driving voltage generator 32 successively generates a high level driving voltage for a comparatively short time and then a low level driving voltage. At this time, the high level driving voltage is applied only for a time required to separate and slightly move the stuck pigment particles 10b from, e.g. the surface of the electrode 26, to prevent any stuck pigment particles 10b from being retained on the surface of the electrode 26. Thereafter, the application of the low level driving voltage at which no electrolysis is caused, is continued for a period of time required to completely move the pigment particles 10b. Thus, the durability, picture image contrast and display quality of the device 20 can be improved.

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(Translation)

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Title of the Invention: ELECTROPHORESIS DISPLAY DEVICE
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Inventor: HIDEYUKI KAWAI
Applicant: NOK CORPORATION

Specification

[Title of the Invention] ELECTROPHORESIS DISPLAY DEVICE

[Claim]

[Claim 1] An electrophoresis display device, comprising:

a light-transmissive first substrate on which at least a light-transmissive first electrode is formed:

a second substrate on which at least a second electrode is formed:

a partition for arranging a surface of the first substrate on which the first electrode is formed and a surface of the second substrate on which the second electrode is formed to face each other:

a dispersion liquid sealed between the two substrates, the dispersion liquid including pigment particles in a colored dispersion medium: and

driving voltage generation means for applying a driving voltage between the first electrode and the second electrode for causing electrophoresis of the pigment particles,

wherein the driving voltage generation means generates a low level driving voltage immediately after a high level driving voltage which is generated for a relatively short time period.

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[Detailed Description of the Invention]
[0001]
[Field of the Invention] The present invention relates to an electrophoresis display device for performing display, utilizing that application of a voltage between electrodes moves charged pigment particles in a medium sealed between the electrodes.

[0002]
[Prior Art] An electrophoresis display device 2 as shown in Figure 6(A) has been developed. This electrophoresis display device includes two substrates 4a and 4b, at least one of which is light-transmissive. These substrates are formed of, for example, glass. The substrates 4a and 4b are opposed to each other by a partition 6 with a prescribed distance kept therebetween. The substrates 4a and 4b and the partition 6 form a closed space. The substrates 4a and 4b respectively have planar transparent electrodes 8a and 8b on inner surfaces thereof which are opposed to each other.

[0003] A dispersion liquid 10 for electrophoresis display is sealed in a sealed space between the substrates 4a and 4b. The dispersion liquid 10 for electrophoresis display includes a colored dispersion medium 10a colored, for example, black and charged white pigment particles 10b dispersed in the dispersion medium 10.

[0004] The electrophoresis display device 2 operates in the following manner. When, for example, a positive voltage is applied to an upper electrode 8a and a negative voltage is applied to a lower electrode 8b as shown in Figure 6(B), the negatively charged white pigment particles 10b dispersed in the colored dispersion medium electrophorese toward the

positive electrode by the Coulomb force, and the white pigment particles 10b adhere to the upper positive electrode 8a. When the electrophoresis display device in such a state is observed from the position of the eye shown in Figure 6(B), a layer formed of the white pigment particles appears white through the transparent electrode 8a and the transparent substrate 4a formed of glass.

[0005] When the polarity of the applied voltage is inverted, as shown in Figure 6(C), the white pigment particles adhere to the electrode on the opposite side and form a layer. When observed from the position of the eye shown in the figure, the layer of the white pigment particles is hidden behind the black dispersion medium. Accordingly, the electrophoresis display panel appears white.

[0006] In such an electrophoresis display device, a driving voltage needs to be continuously applied while the colored pigment particles are moving. In the case where the application time period is excessively short, the colored pigment particles cannot reach the electrode, resulting in a reduction in the display contrast. Therefore, in a conventional device, a driving voltage is generally applied for several ten to several hundred milliseconds. The moving speed of the pigment particles, i.e., the display change speed is in proportion to the driving voltage.

[0007] Even when the application of the driving voltage is stopped, the white pigment particle layer adhering to the electrode is maintained in the adhesion state by the intermolecule gravitational force. Accordingly, once the white pigment particle layer adheres to the electrodes, application of the voltage is not specifically necessary except for the regular application of the voltage for maintaining the

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adhesion state. An electrophoresis display device structured to apply a driving voltage regularly in order to maintain the adhesion state is disclosed in, for example, Japanese Laid-Open Publication No. 3-213827.

[0008]
[Problems to be Solved by the Invention] While the pigment particles adhere to one of the electrodes, the particles are attracted to a surface of the electrode by the inter-molecule gravitational force. In order to separate the particles from the surface to change the display state, a high driving voltage is required. When the driving voltage is excessively low, the particles remain on the surface of the electrode, causing a reduction in the contrast or display quality. However, when the driving voltage is excessively high, the deterioration of the dispersion liquid is promoted since the driving voltage needs to be continuously applied for several ten to several hundred milliseconds as described above. Thus, the life of the display device is shortened. One example of the deterioration of the dispersion liquid is the generation of air bubbles caused by the electrolysis of the moisture component in the dispersion liquid.

[0009] Accordingly, in a conventional device, when the display quality of the electrophoresis display device is given priority, the driving voltage is set at a relatively high level of about 70 to 100 V; whereas when the durability is given priority over the display quality, the driving voltage is set at a relatively low level. The present invention, made in light of the circumstances, has an objective of providing an electrophoresis display device which prevents deterioration of the dispersion liquid, is superior in durability, and has improved contrast and display quality.

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[0010]
[Means for Solving the Problems] In order to achieve the above-described objective, an electrophoresis display device according to the present invention includes a light-transmissive first substrate on which at least a light-transmissive first electrode is formed: a second substrate on which at least a second electrode is formed: a partition for arranging a surface of the first substrate on which the first electrode is formed and a surface of the second substrate on which the second electrode is formed face each other: a dispersion liquid sealed between the two substrates, the dispersion liquid including pigment particles in a colored dispersion medium: and driving voltage generation means for applying a driving voltage between the first electrode and the second electrode for causing electrophoresis of the pigment particles. The driving voltage generation means generates a low level driving voltage immediately after a high level driving voltage which is generated for a relative short time period.

[0011] In the present invention, the absolute value of the high level driving voltage is determined in accordance with the type of the dispersion liquid or the like and is not specifically limited. The absolute value is, for example, 70 to 100 v. The application time period of the high level driving voltage is preferably as short as possible. Since an excessively short application time period cannot separate the pigment particles from the electrode, the application time period is 1 to 20 ms, and preferably about several milliseconds.

[0012] The absolute value of the low level driving voltage is determined in accordance with the type of the dispersion liquid or the like and is not specifically limited. The ab-

solute value is, for example, 30 to 50 V. When the driving voltage is 30 V or less, the electrophoresis phenomenon itself tends not to be caused: and when the driving voltage is 50 V or more, a durability problem occurs. Accordingly, the above-described range is preferable. The application time period of the low level driving voltage is preferably the time period required for the pigment particles to completely move from one of the electrodes to the other electrode. Specifically, a time period of several ten to several hundred milliseconds is preferable.

[0013] The present inventor paid attention to the fact that the maximum driving voltage is required for separating the pigment particles from the surface of the electrode and that the inter-molecule gravitational force is drastically reduced after the pigment particles are slightly separated, and completed the present invention. In other words, in an electrophoresis display device according to the present invention, a high level driving voltage is applied only for a time period required to separate the pigment particles slightly, thus preventing the pigment particles from remaining adhering to the electrode. Thereafter, a low level driving voltage is continuously applied until the movement of the particles is completed to such an extent to prevent electrolysis.

[0014] Therefore, in an electrophoresis display device according to the present invention, deterioration of the dispersion liquid by the driving voltage is avoided, and thus the durability of the device is improved. The pigment particles are also prevented from remaining adhering to the electrode, and thus the contrast and display quality can be enhanced. That is, according to the present invention, ful-

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fillment of the contradicting demands, which is impossible in the conventional device is realized.

[0015]
[Examples] Hereinafter, an electrophoresis display device according to the present invention will be described in detail by way of examples shown in the figures.

Example 1

Figure 1(A) is a schematic cross-sectional view of an electrophoresis display device in one example according to the present invention, and Figure 1(B) is a view illustrating a driving voltage waveform of a driving voltage generation device shown in Figure 1(A).

[0016] As shown in Figure 1(A), an electrophoresis display device 20 in one example of the present invention includes a first substrate 22 and a second substrate 24. A partition 30 is provided along the periphery of the substrates 22 and 24 in order to keep a prescribed distance between the substrates 22 and 24. The first substrate 22 is formed of a light-transmissive plate of, for example, transparent glass. On a surface of the first substrate 22 which is opposed to the second substrate 24, a first electrode 26 is formed. The first electrode 26 is formed of, for example, an indium tin oxide (ITO) film. The first electrode 26 is formed on the entire display plane of the first substrate 22, and a mask having a light-transmissive pattern (display pattern) is provided thereon. Alternatively, the first electrode 26 can be provided on the surface of the first substrate 22 in a desirable pattern in accordance with the display pattern.

[0017] The second substrate 24 is not necessarily transparent, but is formed of, for example, glass. On a surface of

the second substrate 24 opposed to the first substrate, a second electrode 28 is formed. The second electrode 28 is not necessarily a transparent electrode, but is formed of, for example, an ITO film.

[0018] The partition 30 for maintaining a prescribed distance between the first substrate 22 and the second substrate 24 also has a function of sealing a sealed space formed by the substrates 22 and 24 and the partition 30. The partition 30 is formed of a sealing agent such as, for example, an epoxy resin. The thickness of the partition 30 (inter-electrode distance) is usually about 20 **μm** to 1 mm.

[0019] The dispersion liquid 10 for electrophoresis display is accommodated in the sealed space formed by the substrates 22 and 24 and the partition 30. The dispersion liquid 10 for electrophoresis display includes a colored dispersion medium 10a and charged pigment particles 10b dispersed in the dispersion medium. The colored dispersion medium 10a is not limited to any material. The colored dispersion medium 10a is, for example, a black dispersion medium, and specifically a hexylbenzene+anthraquinone dye or the like is used. The pigment particles 10b are not limited to any material. For example, white pigment particles or other colored pigment particles are used. Specifically, for example, zinc sulfide (ZnS) particles having an outer diameter of about 0.8 to 1.2 **μm** including a surfactant added thereto are used.

[0020] In this example, a driving voltage generation device 32 is connected between the first electrode 26 and the second electrode 28. The driving voltage generation device 32 generates a driving voltage having a driving voltage waveform shown in, for example, Figure 1(B). As shown in Figure 1(B), the driving voltage includes a high level driving

voltage Vh generated for a relative short time period and a low level driving voltage Vl generated immediately thereafter. In this example, the voltage value of the high driving voltage Vh is about 70 to 100 V, and an application time period Th thereof is about several milliseconds. In this example, the voltage value of the low driving voltage Vl is about 30 to 50 V, and an application time period Tl thereof is several ten to several hundred milliseconds.

[0021] In the electrophoresis display device 20 in this example, a high level driving voltage Vh is applied only for a time period required for slightly separating the pigment particles 10b shown in Figure 1 from the one of the electrode, i.e., the second electrode 28, thereby preventing the pigment particles 10b from remaining adhering to the electrode 28. Thereafter, a low level driving voltage Vl is continuously applied until the movement of the particles 10b from the second electrode 28 to the first electrode 26 is completed to such an extent to prevent electrolysis. As a result, the pigment particles 10b are mostly separated from a surface of the second electrode 28 and adhere to the first electrode 26. Thus, the pigment particles 10b are prevented from remaining adhering to the second electrode 28. Since the level of the low-level driving voltage Vl is sufficiently low to prevent electrolysis of the dispersion liquid 10, the dispersion liquid 10 is not deteriorated. When the pigment particles 10b move to the first electrode 26, the display plane of the first substrate 22 is colored by the pigment particles 22, and thus a prescribed display is obtained.

[0022] By contrast, in order to separate the pigment particles 10b from the other electrode (i.e., the first electrode 26) and move the pigment particles 10b toward the second

electrode 28, a driving electrode having the same waveform as but different polarities from the driving waveform shown in Figure 1(B) is applied between the electrodes 26 and 28 by the driving voltage generation device 32. Thus, in the same manner as described above, the pigment particles 10b are mostly separated from the first electrode 26 and adhere to the second electrode 28, leaving no pigment particles 10b adhering to the first electrode 26. As a result, the pigment particles 10b are hidden behind the dispersion medium 10a when seen from the display plane of the first substrate 22. The display plane is colored by the dispersion medium 10a, and a different display state from the above is realized.

[0023] Accordingly, in the electrophoresis display device 20 in this example, deterioration of the dispersion liquid 10 by the driving voltage is avoided, and the durability of the device 20 is improved. The pigment particles 10b are prevented from remaining adhering to the electrode, and thus the contrast and display quality can be enhanced.

[0024] Example 2

Figure 2 is a plan view of an example of a display plane of an electrophoresis display device in another example according to the present invention. Figure 3 is a cross-sectional view of Figure 2 taken along line III-III. Figure 4(A) is a block diagram illustrating an example of a driving voltage generation circuit shown in Figure 3, and Figure 4(B) is a timing diagram illustrating operation timing of the circuit shown in Figure 4(A). Figure 5 is a timing diagram illustrating a driving waveform for displaying 0 and 1 on the plane shown in Figure 2.

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[0025] As shown in Figures 2 and 3, an electrophoresis display device 20a in a second example of the present invention includes a first substrate 22a and a second substrate 24a. A partition 30a is provided along the periphery of the substrates 22a and 24a in order to keep a prescribed distance between the substrates 22a and 24a.

[0026] The first substrate 22a is formed of a light-transmissive plate of, for example, glass. On a surface of the first substrate 22a which is opposed to the second substrate 24a, a first electrode 26a is formed. The first electrode 26a is formed of, for example, an indium tin oxide (ITO) film. The first electrode 26a is formed on the entire display plane of the first substrate 22a. The first electrode 26a acts as a common electrode and is grounded. A light blocking mask 40 having a light-transmissive pattern 42 (display pattern) for displaying numerals of 0 through 9 is provided on a surface of the first electrode 26a. Only the transmissive pattern 42 in the light blocking mask 40 is light-transmissive, and has seven lengthy holes arranged in the shape of the numeral "8" in order to display numerals of 0 through 9.

[0027] The second substrates 24a is not necessarily transparent, but is formed of, for example, glass. On a surface of the second substrates 24a opposed to the first substrate, second electrodes 28a through 28g are formed. The second electrodes 28a through 28g are not necessarily transparent electrodes, but are formed of, for example, ITO films. In this example, the second electrodes 28a through 28g act as segment electrodes, and are respectively patterned so as to include the lengthy holes of the light-transmissive pattern 42.

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[0028] The partition 30a for maintaining a prescribed distance between the first substrate 22a and the second substrate 24a also has a function of sealing a sealed space formed by the substrates 22a and 24a and the partition 30a. The partition 30a is formed of a sealing agent such as, for example, an epoxy resin. The thickness of the partition 30a (inter-electrode distance) is usually about 20 μm to 1 mm.

[0029] A dispersion liquid 10 for electrophoresis display is accommodated in the sealed space formed by the substrates 22a and 24a and the partition 30a. The dispersion liquid 10 for electrophoresis display includes a colored dispersion medium 10a and charged pigment particles 10b dispersed in the dispersion medium. The colored dispersion medium 10a is not limited to any material. The colored dispersion medium 10a is, for example, a black dispersion medium, and specifically a hexylbenzene+anthraquinone dye or the like is used. The pigment particles 10b are not limited to any material. For example, white pigment particles or other colored pigment particles are used. Specifically, for example, zinc sulfide (ZnS) particles having an outer diameter of about 0.8 to 1.2 μm including a surfactant added thereto or the like are used.

[0030] In this example, driving voltages are applied to the electrodes 28a through 28g acting as the segment electrodes separately from one another by an electrode selection circuit 44 shown in Figure 3. The electrode selection circuit 44 is connected to a positive driving voltage generation circuit 32a, a negative driving voltage generation circuit 32b, and a display data control section 46. The display data control section 46 is connected to input means such as, for example, a keyboard or ten key. Display data is input from the input means to control the electrode selection cir-

cuit 44, so that a desired display is realized on the display plane of the display device 20a.

[0031] The positive driving voltage generation circuit 32a and the negative driving voltage generation circuit 32b are different only in that whether the driving voltage is positive or negative. The driving waveforms of the driving voltages output by the circuits have the same absolute value. The waveform of the driving voltage shown in Figure 1(B) is output. Such a driving voltage is selectively applied by the electrode selection circuit 44 to any one of the second electrodes 28a through 28g acting as the segment electrodes.

[0032] The positive driving voltage generation circuit 32a and the negative driving voltage generation circuit 32b, which have a circuit configuration shown in, for example, Figure 4(A), each include a high voltage generation section 48, a low voltage generation section 50, a control section 52, and switches 53 and 54. The high voltage generation section 48 generates a high level driving voltage Vh shown in Figure 1(B). The low voltage generation section 50 generates a low level diving voltage Vl shown in Figure 1(B). The voltages are switched by switching the switches 53 and 54 by the control section 52. In other words, as shown in Figure 4(B), the switch 52 is first turned on: and a short time period Th later, the switch 53 is turned off and the switch 54 is turned on. As a result, the high level voltage Vh shown in Figure 1(B) is obtained for a relatively short time period. Next, a voltage from the low voltage generation section 50 is applied to the electrode selection circuit 44 until time tl later, when the switch 54 is turned off. As a result, the low level driving voltage Vl shown in Figure 1(B) can be obtained immediately after the driving voltage Vh.

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[0033] Next, a specific waveform of the driving voltage for displaying, for example, 0 on the display plane of the first substrate 22 and then displaying 1, using the electrophoresis display device 20a shown in Figures 2 through 4, will be described. In order to display 0 on the display plane as shown in Figure 5(A), positive driving voltages of the waveform shown in Figure 1(B) are respectively applied to the second electrodes 28a through 28f, and a negative driving voltage having the same absolute value as but opposite polarity to the above-described driving voltages is applied to only the second electrode 28g. As a result, the pigment particles 10b move from the second electrodes 28a through 28f to the first electrode 26a acting as a common electrode in accordance with areas of the pattern 42 corresponding to 0, leaving no pigment particles 10b remaining adhering to the second electrodes 28a through 28f. Thus, 0 is displayed by the colored pigment particles 10b

[0034] Next, in order to change the display of 0 into 1, positive driving voltages of the driving waveform shown in Figure 1(B) are still applied to the second electrodes 28a and 28b acting as the segment electrodes, and the polarity of the driving voltages applied to the second electrodes 28c through 28f is changed from positive to negative. A negative electrode is again applied to the second electrode 28g. As a result, the voltage applied to the second electrodes 28c through 28f acting as the segment electrodes is changed from positive to negative, and the pigment particles 10b corresponding to these electrodes are separated from the first electrode 26a and move to the second electrode 28a by electrophoresis. At this point, since a high driving voltage -Vh is applied initially, the pigment particles 10b are separated from the first electrode 26a without remaining ad-

hering to the first electrode 26a. The level of the low level driving voltage Vl which is applied thereafter is sufficiently low to prevent electrolysis of the dispersion liquid 10. The application of the low level driving voltage Vl is continued until the particles 10b are completely moved from the first electrode 26a to the second electrode 28a.

[0035] As a result, the pigment particles 10b remain on the first electrode only in areas of the pattern 42 corresponding to the second electrodes 28a and 28b (hatched areas), and the pigment particles 10b move to the second electrode 28c through 28g corresponding to the rest of the pattern 42. Thus, 1 is displayed by the colored pigment particles 10b. In the electrophoresis display device 20 in this example, a high level driving voltage -Vh is applied only for the time period required for slightly separating the pigment particles 10b shown in Figure 3 from one of the electrodes, i.e., the first electrode 26a, thereby preventing the pigment particles 10b from remaining adhering to the first electrode 26a. Thereafter, a low level driving voltage -Vl is continuously applied until the particles 10b are completely moved from the first electrode 26a to the second electrode 28a to such an extent to prevent electrolysis of the dispersion 10 for electrophoresis display. As a result, the pigment particles 10b are mostly moved from the first electrode 26a and adhere to the second electrode 28a in the corresponding areas, thus preventing the pigment particles 10b from remaining adhering to the first electrode 26a. Since the level of the low level driving voltage Vl is sufficiently low to prevent electrolysis of the dispersion liquid 10, the dispersion liquid is not deteriorated.

[0036] In order to display the other numerals on the display plane shown in Figure 2, an optional positive or negative

driving voltage is applied to desired second electrodes among the second electrodes 28a through 28g by the positive driving voltage generation circuit 32a or the negative driving voltage generation circuit 32b through the electrode selection circuit 44.

[0037] According to the electrophoresis display device 20a in this example, deterioration of the dispersion liquid 10 by the driving voltage is avoided, and the durability of the display device 20a is improved. The remaining adhesion of the pigment particles 10b is prevented, and thus the contrast and display quality can be enhanced.

[0038] The present invention is not limited to the above-described examples, but various modifications can be made within the scope of the present invention. For example, the images displayed on the display plane of the electrophoresis display device are not limited to the images mentioned in the above-described example. Various images can be displayed by changing the shape and arrangement of the light-transmissive pattern 42 of the mask 40 shown in Figures 2 and 3 and also changing the shape, number and arrangement pattern of the second electrodes 28a through 28g acting as the segment electrodes.

[0039] The color and material of the pigment particles 10b and the dispersion medium 10a in the dispersion liquid 10 can be altered in various ways.

[0040]
[Effect of the Invention] As described above, in an electrophoresis display device according to the present invention, deterioration of the dispersion liquid by the driving voltage is avoided, and the durability of the device is im-

proved. The remaining adhesion of the pigment particles is also avoided, and thus the contrast and display quality can be enhanced. That is, according to the present invention, the fulfillment of the contradicting demands, which is impossible in the conventional devices, is realized.

[Brief Description of the Drawings]
[Figure 1] Figure 1(A) is a schematic cross-sectional view of an electrophoresis display device in one example according to the present invention, and Figure 1(B) is a view showing a driving waveform of a driving voltage generation device shown in Figure 1(A).

[Figure 2] Figure 2 is a plan view illustrating one example of a display plane of the electrophoresis display device in another example according to the present invention.

[Figure 3] Figure 3 is a cross-sectional view of Figure 2 taken along line III-III.

[Figure 4] Figure 4(A) is a block diagram illustrating one example of the driving voltage generation circuit shown in Figure 3, and Figure 4(B) is a timing diagram illustrating operation timing of the circuit shown in Figure 4(A).

[Figure 5] Figure 5 is a timing diagram'illustrating a driving waveform for displaying 0 and 1 on the display plane shown in Figure 2.

[Figure 6] Figures 6(A) through (C) are schematic views showing the principle of an electrophoresis display device.

[Description of the Reference Numerals]
10 . . . Dispersion liquid

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10a . . . Dispersion medium
10b ... Pigment particles
20, 20a . . . Electrophoresis display device
22, 22a . . . First substrate
24, 24a . . . Second substrate
26, 26a . . . First electrode
28, 28a through 28g . . . Second electrode
30 . . . Partition
32 . . . Driving voltage generation device
32a . . . Positive driving voltage generation device
32b ... Negative driving voltage generation device
40 . . . Light blocking mask
42 . . . Light-transmissive pattern
44 . . . Electrode selection circuit
46 ... Display data control section

SHUSAKU YAMAMOTO

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[Abstract]
[Objective] To provide an electrophoresis display device which does not deteriorate the dispersion liquid, is superior in durability and improves the contrast and display quality.

[Means for Achieving the Objective] Includes a light-transmissive first substrate 22 on which at least a light-transmissive first electrode 26 is formed: a second substrate 24 on which at least a second electrode 28 is formed: a partition 30 for arranging a surface of the first substrate 22 on which the first electrode 26 is formed and a surface of the second substrate 24 on which the second electrode 28 is formed to face each other: a dispersion liquid 10 sealed between the two substrates 22 and 24, the dispersion liquid 10 including pigment particles 10b in a colored dispersion medium 10a; and a driving voltage generation device 32 for applying a driving voltage between the first electrode 22 and the second electrode 24 for causing electrophoresis of the pigment particles. The driving voltage generation device 32 generates a low level driving voltage Vl immediately after a high level driving voltage Vh which is generated for a relative short time period.

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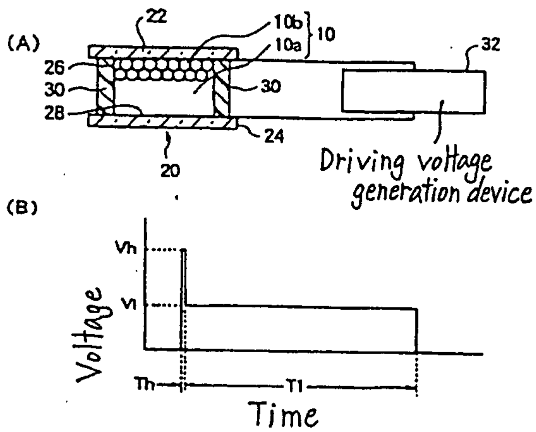
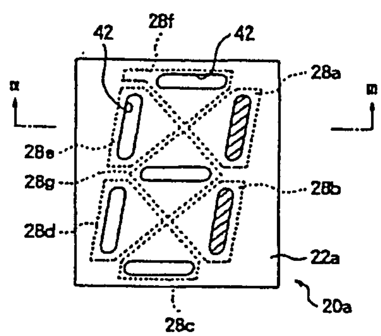
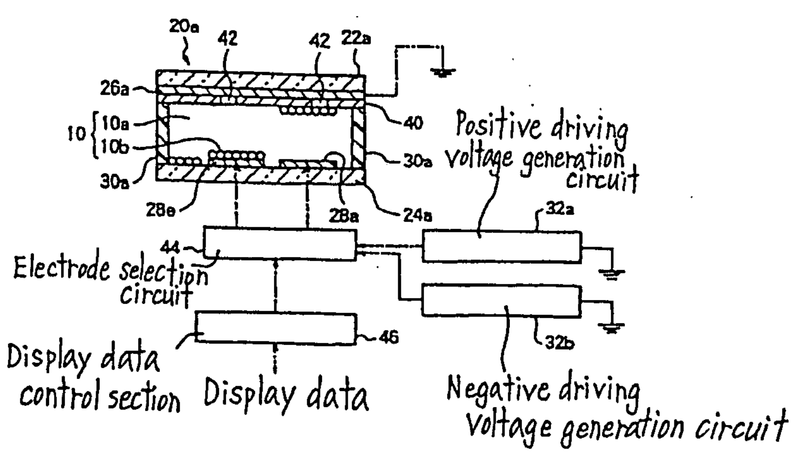
[Fig. 1]



[Fig. 2]



[Fig. 3]



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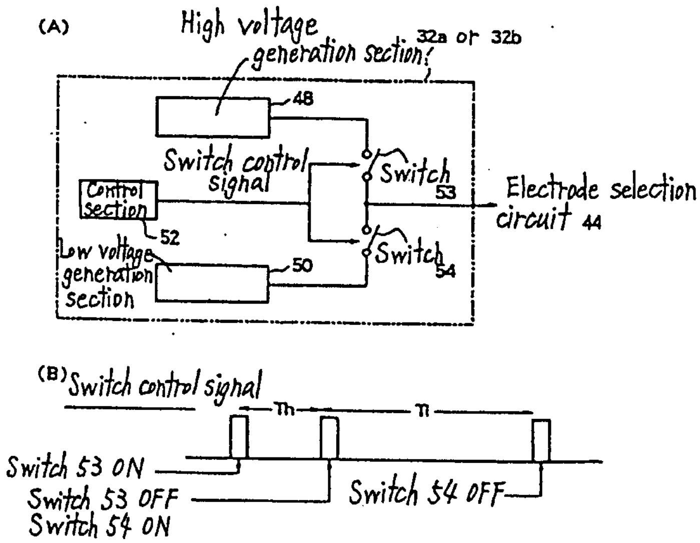
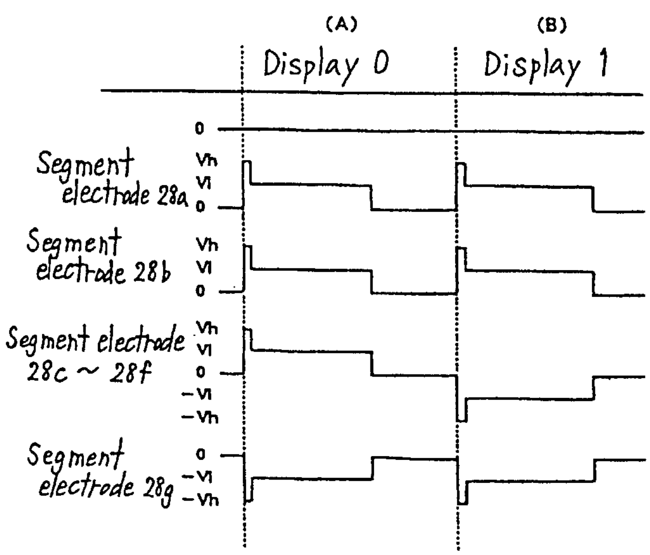
[Fig. 4]



[Fig. 5]



[Fig. 6]